Comparison of DMC, UltraCam, and ADS40-52 Data

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- John Wood, *Texas A&M Harte Research Institute for Gulf of Mexico Studies*
- George Lee and Greg Stensaas, *USGS*
- Professionals at *Fugro Earthdata, Sanborn, and Photo Science*

Dedication

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This presentation is dedicated to Dennis Pridgen of the Texas Parks and Wildlife Department who was taken from us in October of 2008. The project would not have been possible without him. We miss his humor, kindness, knowledge, and commitment to protecting the health of Texas's benthic ecosystems.

Background

- The coast of Texas supports a wide diversity of marine habitats as well as providing an abundance of recreational opportunities and contributing significantly to the Texas economy.
- Dominated by submerged seagrass meadows, the bays provide essential nursery habitats for estuarine fisheries and support a wide variety of wildlife and marine life including shrimp, crabs, juvenile game fish, sea turtles, shorebirds, and waterfowl (TPWD, 2007a).
- Over the last 30 years, the bays have been significantly impacted by human endeavors.
- Managing and protecting this diverse and sensitive resource requires knowledge of the state's coastal marine habitat distribution and an understanding of the causes of change in these habitats over time.

Background

- Much of the concern about prop scar impact has been focused on Redfish Bay, a 62 square mile area located just north of Corpus Christi, Texas
- To better understand the impact of prop scars on seagrass beds, NOAA's Coastal Services Center (CSC), the Texas Parks and Wildlife Department (TPWD) and the Texas A&M University Center for Coastal Studies cooperated in a study to examine propeller scars in the seagrass habitat of Redfish Bay.
- The map produced for the study allowed for eventual quantitative monitoring of prop scan impacts.

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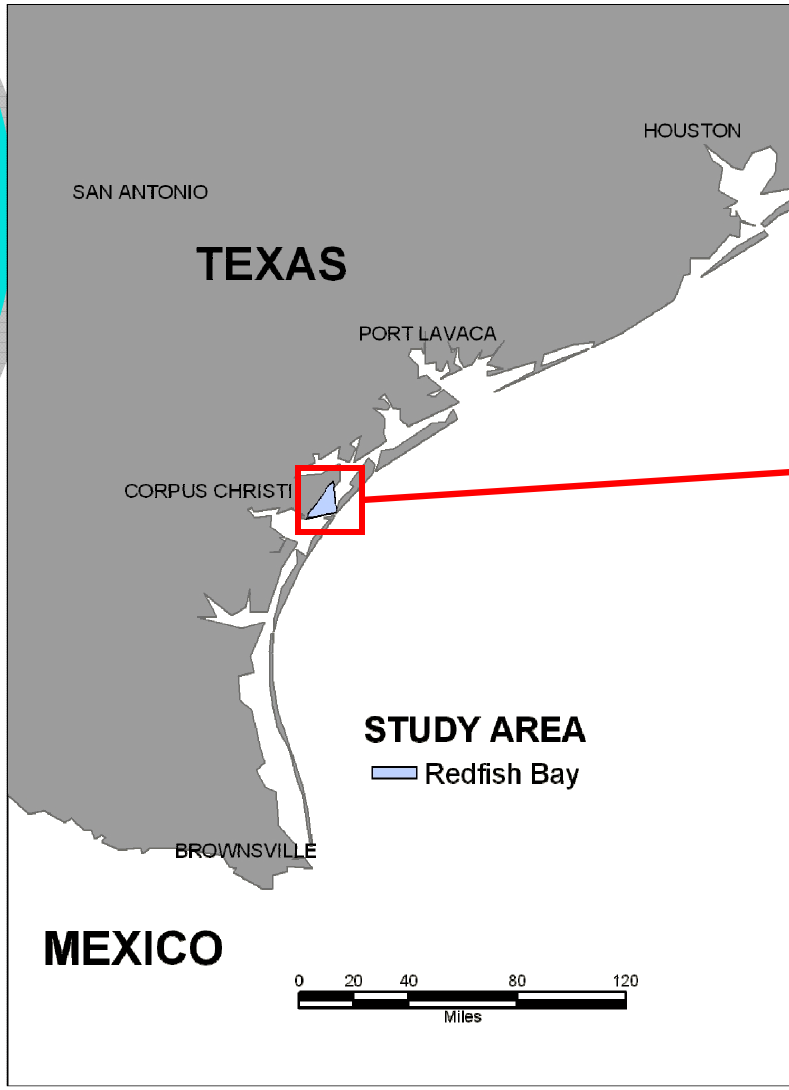
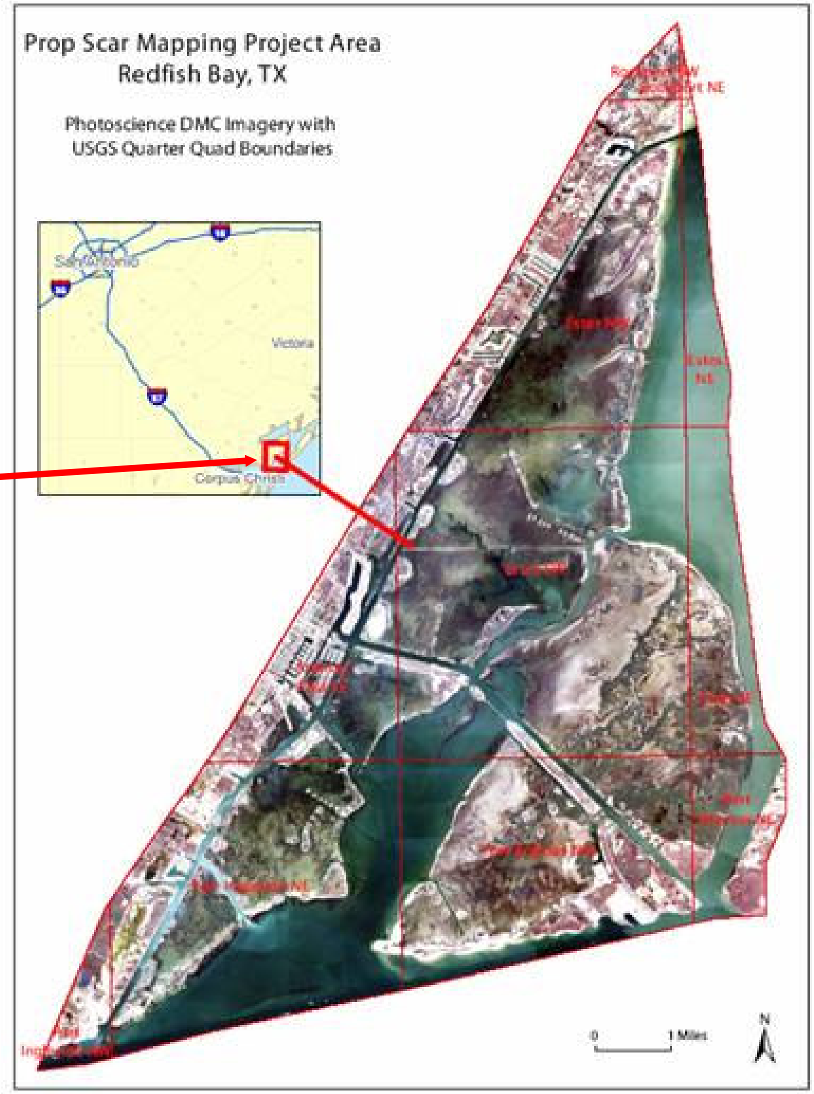
Location of Redfish Bay, Texas, USA





Project Goals

- Document differences between the three airborne multi-spectral imagery sensors.
- Document each sensor’s suitability for mapping propeller scars and benthic habitat features, and
- Create recommendations for future benthic mapping efforts.

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Propeller Scars in Seagrass

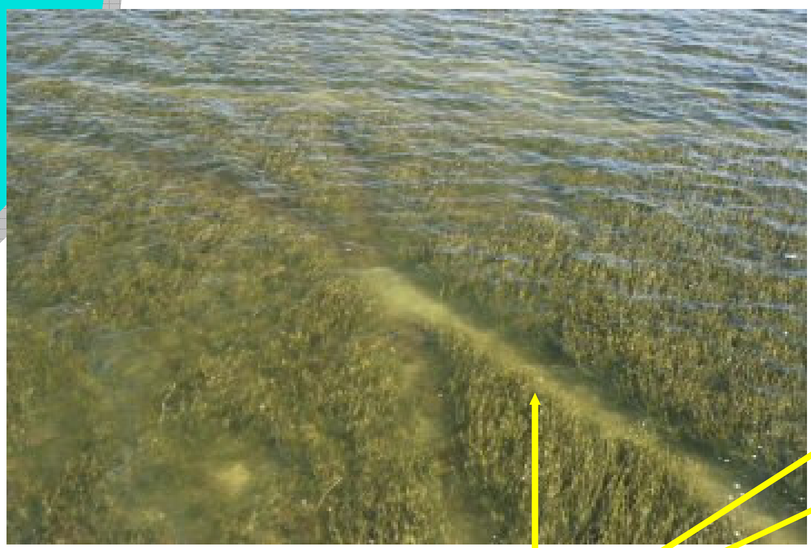
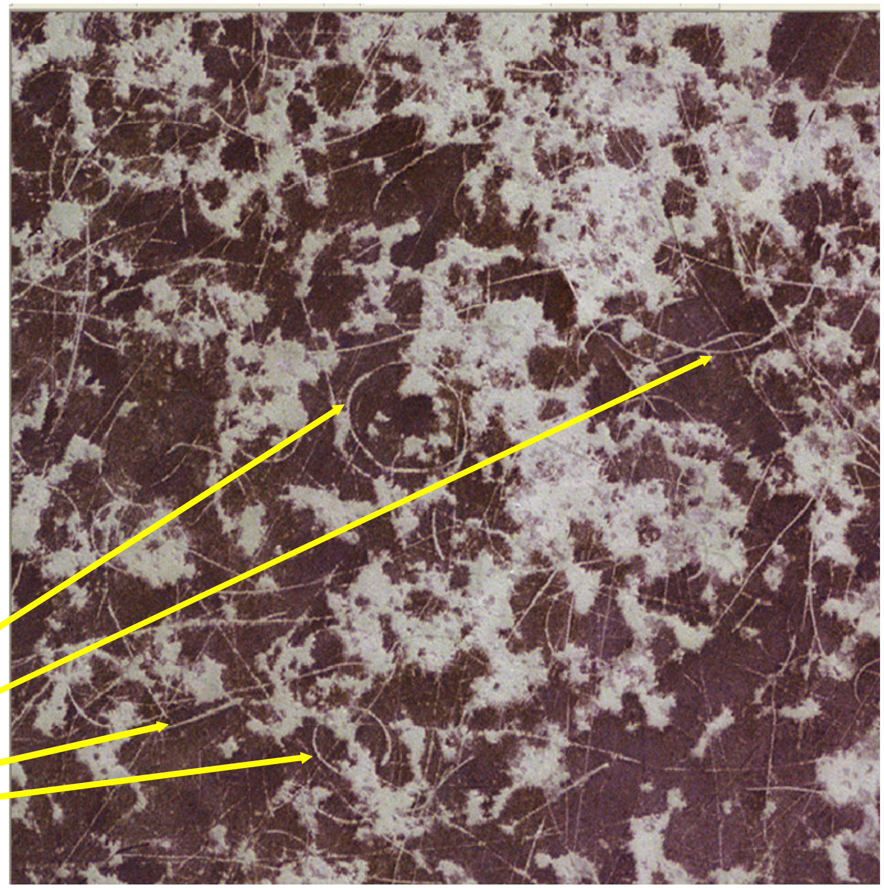


Photo taken from a boat courtesy of TPWD



Propeller Scars

Digital airborne imagery

2. Sensors Used in This Project

- Leica (www.leica-geosystems.com) ADS40-52 operated by Fugro-Earthdata, Inc. (www.Earthdata.com) ,
- Microsoft UltraCam[1] (www.microsoft.com/ultracam/) operated by Sanborn (www.Sanborn.com) , and
- Intergraph Digital Mapping Camera (DMC) (www.intergraph.com) operated by PhotoScience (www.PhotoScience.com) .

[1] After the imagery was collected for this project, Microsoft released the UltraCamX, with updated capabilities and new lenses.

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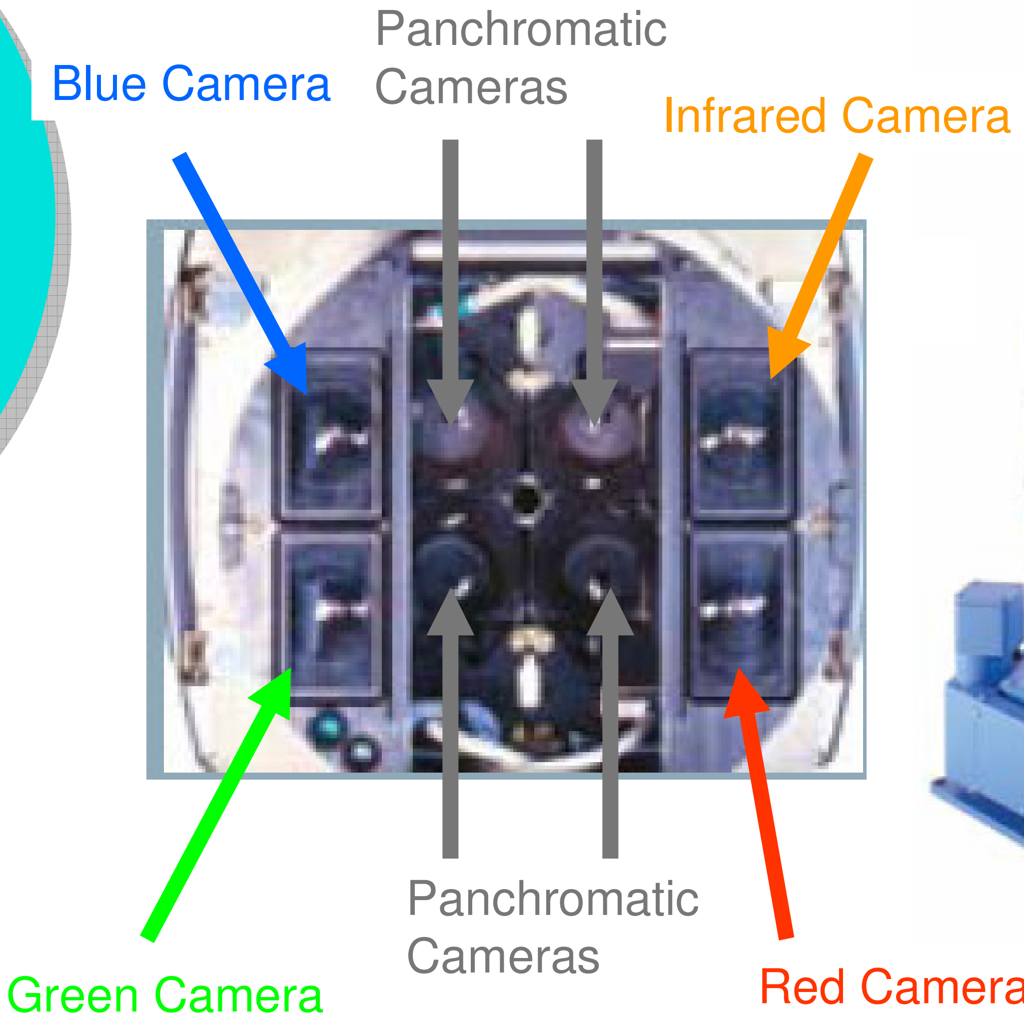
DMC



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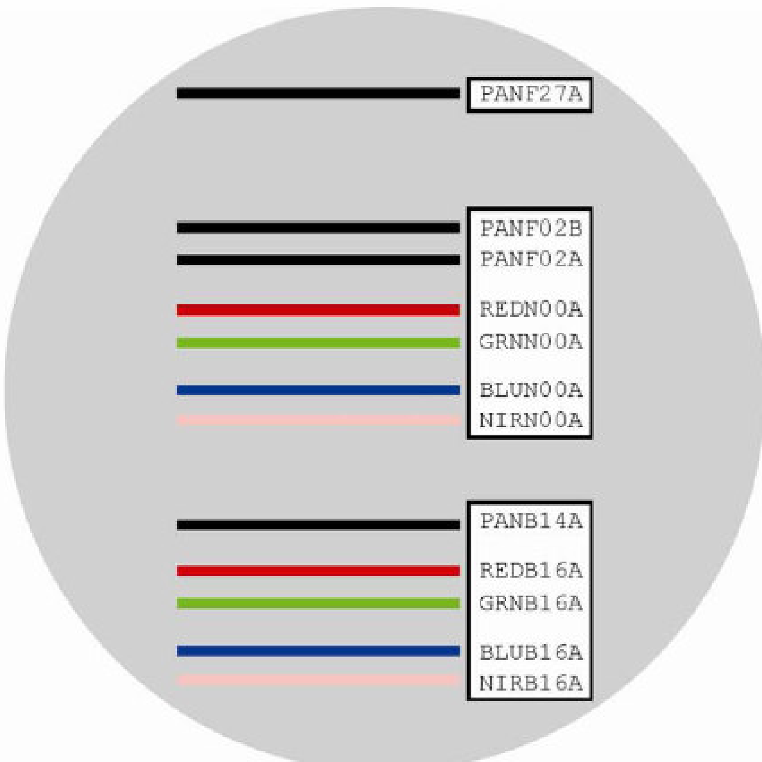
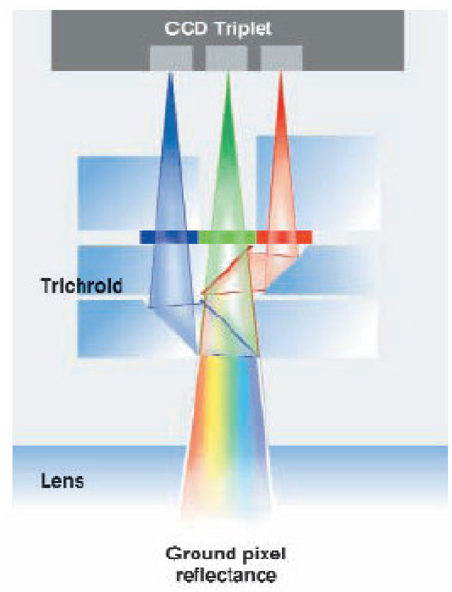
UltraCamD

ADS40-52


PANF27A
PANF02B
PANF02A
REDN00A
GRNN00A
BLUN00A
NIRN00A
PANB14A
REDB16A
GRNB16A
BLUB16A
NIRB16A


CCD Triplet
Trichroid
Lens
Ground pixel
reflectance

	UltraCam	*ADS 40-52*	*DMC*
Sensor/Image Characteristics			
Operation	Frame grabbing	Linear array pushbroom	Frame grabbing
Image Capture	8 camera heads	12 linear pushbroom sensor heads	8 camera heads
Smallest Ground Sample	2.7 cm panchromatic at 1,000 feet above ground	5 cm panchromatic & multispectral at 1,500 feet above ground	3 cm panchromatic at 1,000 feet above ground
Panchromatic Spectral Resolution	380-720nm	465-680nm	400-950nm
MultiSpectral Spectral Resolution			
blue	380-580nm	428-492nm	400-580nm
green	480-640nm	533-587nm	500-650nm
red	580-700nm	608-662nm	590-675nm
infrared	680-940nm	833-887nm	675-850nm
Radiometric Resolution	12+ bit, 14 bit ADC, 16 bit storage	12 bit (16 bit A/D converter and Data channel)	12 bit
Array Size	11,500 x 7,500 pixels (after pan/MS fusing)	12 lines x 12,000 pixels across track	13824 pixel x 7680 pixel (after pan/MS fusing)
Camera System Details			
Lens	Schneider-Kreuznach lenses	Leica DO64 telecentric and temperature stabilized lens	customized Zeiss lens and shutter design
Field of View	55/61° (cross track, along track)	64° across track	69.4° across flight line, 42° in flight direction
Focal Length	100 mm (Pan), 28 mm (MS)	62.5 mm	120 mm
F-Stop	f/5.6 (Pan), f/4 (MS)	fixed at f/4	f/4 to f/22
Shutter	1/500 to 1/60	Not required in line sensors	1/50 to 1/300
Aspect Ratio	11.5:7.5		1.75:1
Frame Rate	1/1.3 frame per second	NA	2.1 seconds per image
Pixel Size	9 micrometers		12 micrometers
Other Specifications			
Sensor Manufacturer	Microsoft	Leica	Intergraph
System Operator for this Project	Sanborn Map Company	Fugro-Earthdata	PhotoScience
Storage	1.5 terabytes (2700 images)	Capacity of mass memory: 0.9 terabytes (exchangeable in-flight)	336 gigabytes (1200 images), can be exchanged during flight
Weight	~110 kilograms for whole system	220 kilograms for working system in the aircraft	80 kilograms main camera, 170 kg complete system
Forward Motion	Yes	Not necessary, inherent in the line sensor principle	Yes, full electronic using TDI
Gyro Stabilized Mount	Yes	Yes	Yes
Co registration of Composite	Image fusion matching	Yes, uses Tetrachroid beam splitter	Sub-pixel image fusion matching

Major Differences

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- The DMC and the UltraCam are framing camera sensors. The ADS40-52 is a pushbroom scanner.
- The DMC and the UltraCam panchromatic cameras collect data at a higher spatial resolution than their multispectral cameras and then “pan sharpen” to bring the multispectral data to the spatial resolution of the panchromatic data. Conversely, the ADS40-52 collects panchromatic and multispectral data at the same spatial resolution.
- The portions of the electromagnetic spectrum captured by the DMC and UltraCam overlap on the borders of the three visible bands. Conversely, there is no band overlap in the ADS40-52.
- The DMC and the UltraCam panchromatic cameras sense energy from the blue to the infra portion of the electromagnetic spectrum. The ADS40-52 panchromatic sensor only sensed energy in the visible bands.

3. *Image Collection*

- To maximize the usefulness of the airborne digital imagery for benthic habitat and propeller scar mapping, NOAA placed stringent conditions on the imagery collection.
- To minimize differences between the image collections due to environment (rather than due to sensor system technical characteristics), NOAA specified that all image collections occur on the same day and within hours of one other.

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Environmental Conditions During Imagery Acquisition

- Weather conditions on the day of the collection were close to optimal due to the diligence of Dennis Pridgen of Texas Parks and Wildlife. Visibility of 10 miles and clear skies resulted from the passage of a cold front the previous day with a high pressure dome passing over the area.
- During the collections, wind speeds ranged from 8 to 13 miles per hour which slightly exceeds the desired speed of 0 to 5 miles per hour.
- Water clarity was very good, with Secchi Disk Visibility exceeding 1.5 meters throughout the area.
- Tides were very low due to north winds over the previous 24 hours having pushed water out of the bays and away from the gulf beaches During the collections, Redfish Bay tidal change was less than 2 inches.
- Considering the complexity of environmental variables possible, conditions were remarkably similar for all three image collections.

Image Pre-processing

- Each image data set was pre-processed in some way to bring the data sets to a common format and standard.
- Processing steps for each data set are listed below

System	*Tile*	*Radiometric Resolution*	*No. Bands/Spectral Resolution*	*Spatial Resolution*	*Processing Steps Required*
ADS40-52	Quarter Quad	8	3 (R, G, B/G, R, NIR)*	0.25 m	Create 4 banded images
UltraCam	Quarter Quarter Quad	8	4 (R, G, B, NIR)	0.25 m	Merge to quarter quad
DMC	Small Rectangle	16	4 (R, G, B, NIR)	0.25 m	Rescale to 8 bit

*Fugro Earthdata delivered two images per quarter quad, 1 true color and one color infrared

4. Imagery Reviews

1. Quantitative Reviews for
   A. Spatial accuracy
   B. Comparison of histograms per band
   C. Edge response, and
   D. Bi-spectral plots of benthic habitat classes
2. Qualitative Reviews by Experts

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A. Spatial Accuracy

- The reported spatial accuracy of all three data sets was much better than the contract standard of ± 5 meters.
- NOAA surveyed 23 points for spatial accuracy determination of which 19 were suitable for accuracy assessment analysis.
  - ✓ Two points were blunders
  - ✓ Two points not on all three data sets

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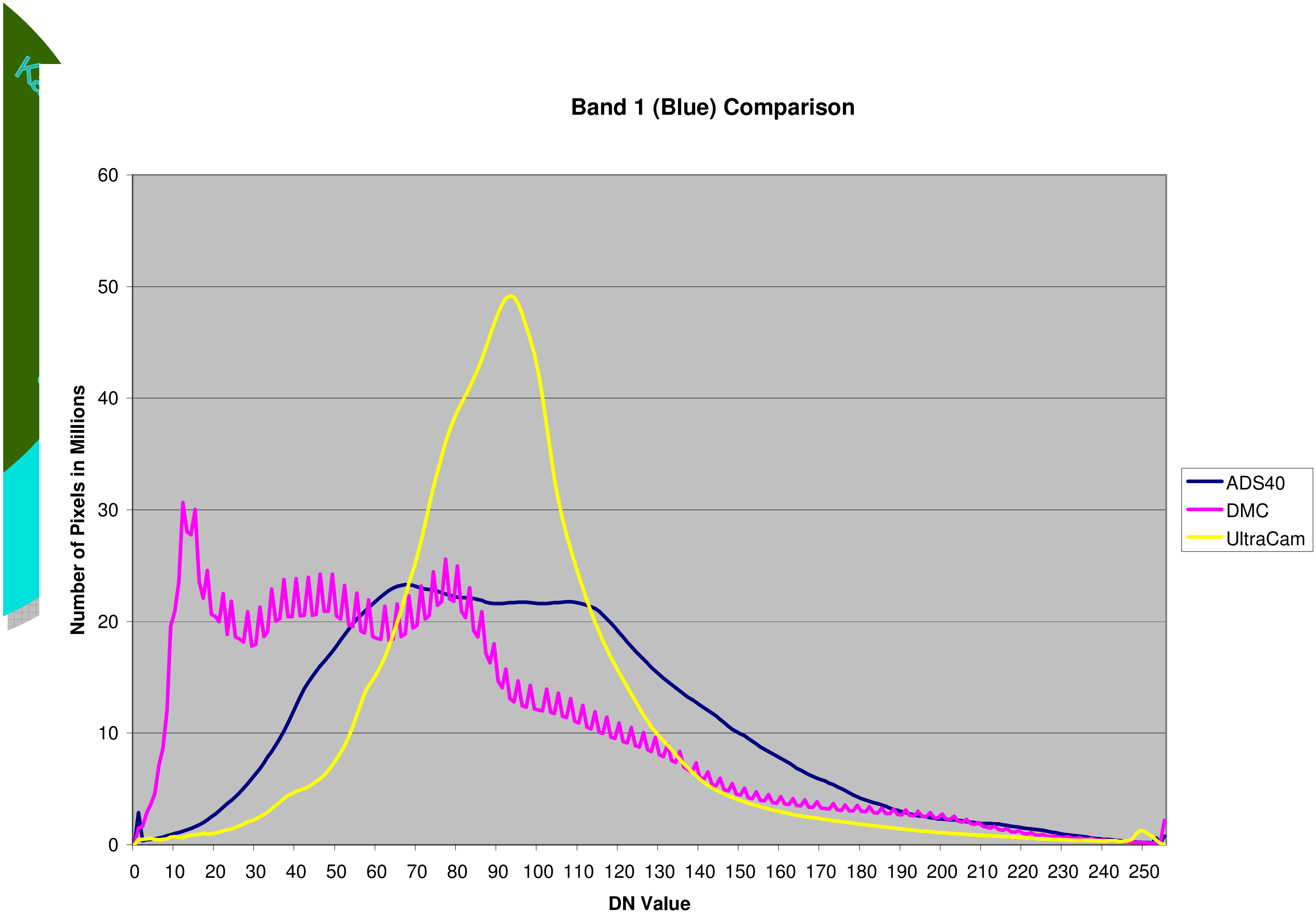
Spatial Accuracy From NOAA Samples

	RMSE	*NSSDA*	95% confidence interval around *RMSE*
DMC	0.395 m	0.684	0.318 to 0.473m
UltraCamD	0.774 m	1.340	0.631 to 0.913m
ADS40-52	0.379 m	0.657	0.318 to 0.473m

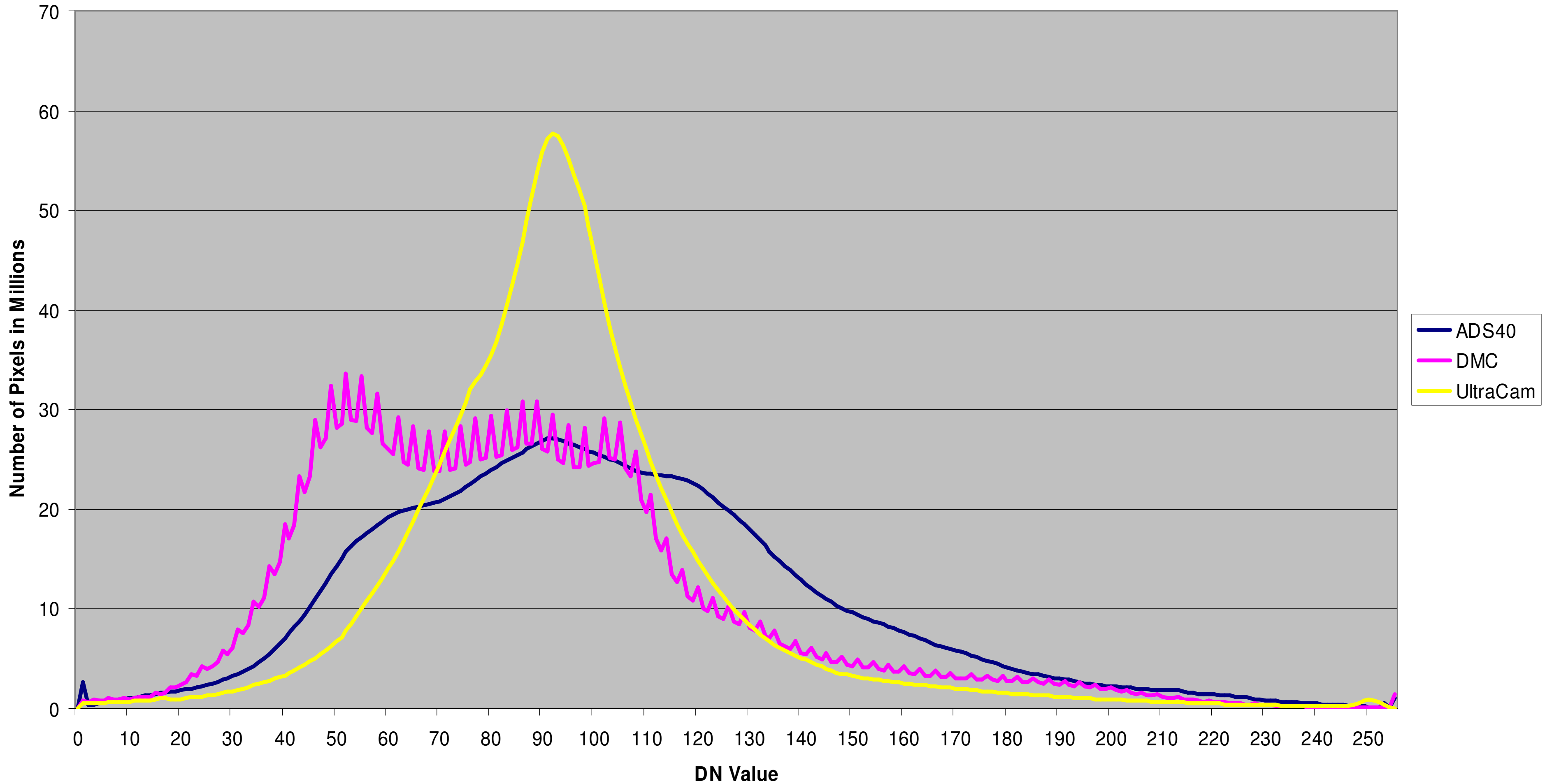
B. Comparison of Histograms

- The following four charts compare the histograms for each band of each data set.
- The UltraCam histograms are surprisingly normally distributed. We believe that the UltraCam histograms are a result of processing by the vendor.

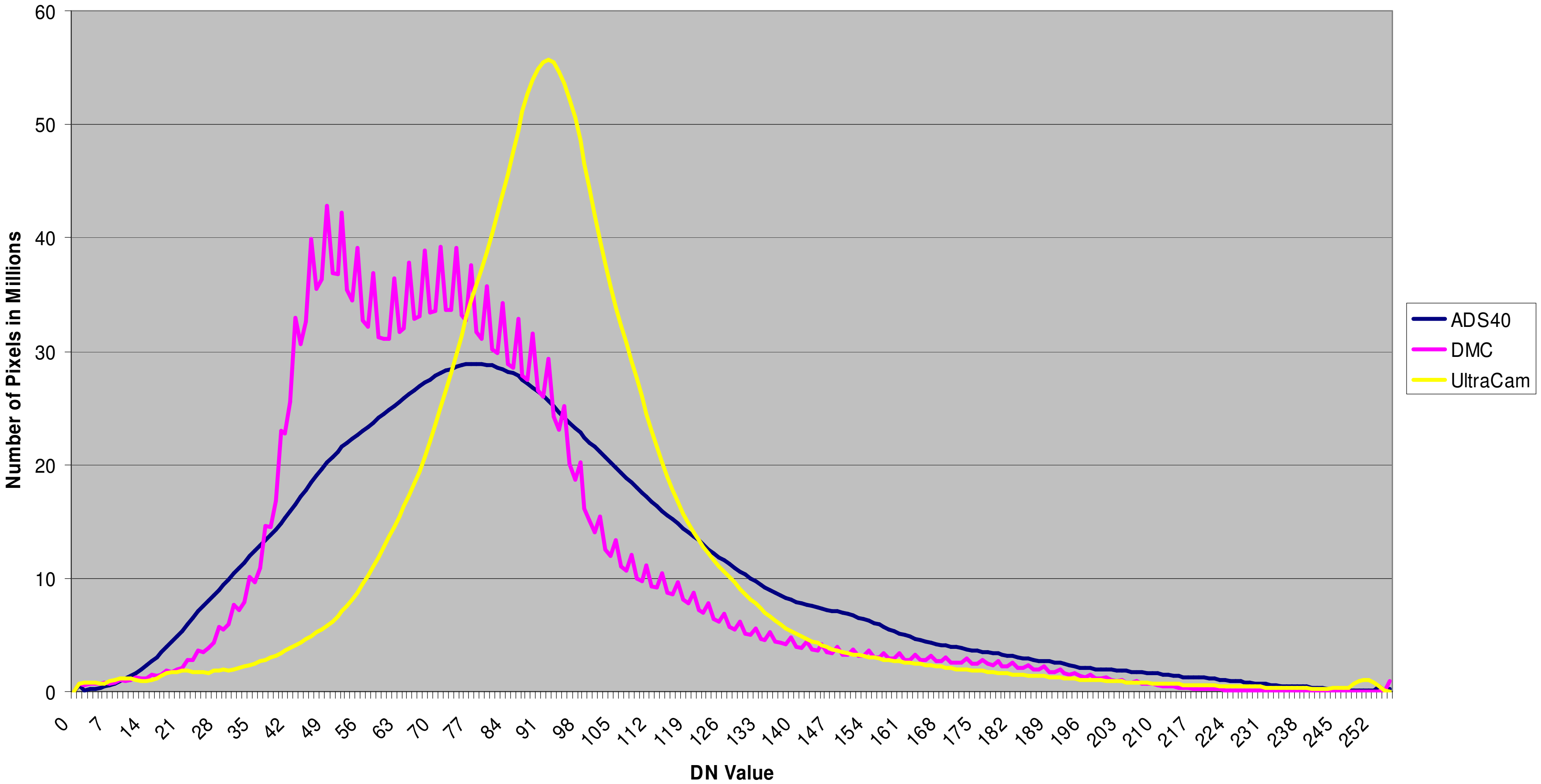


Band 1 (Blue) Comparison
Number of Pixels in Millions
DN Value
0
10
20
30
40
50
60
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210 220 230 240 250
ADS40
DMC
UltraCam

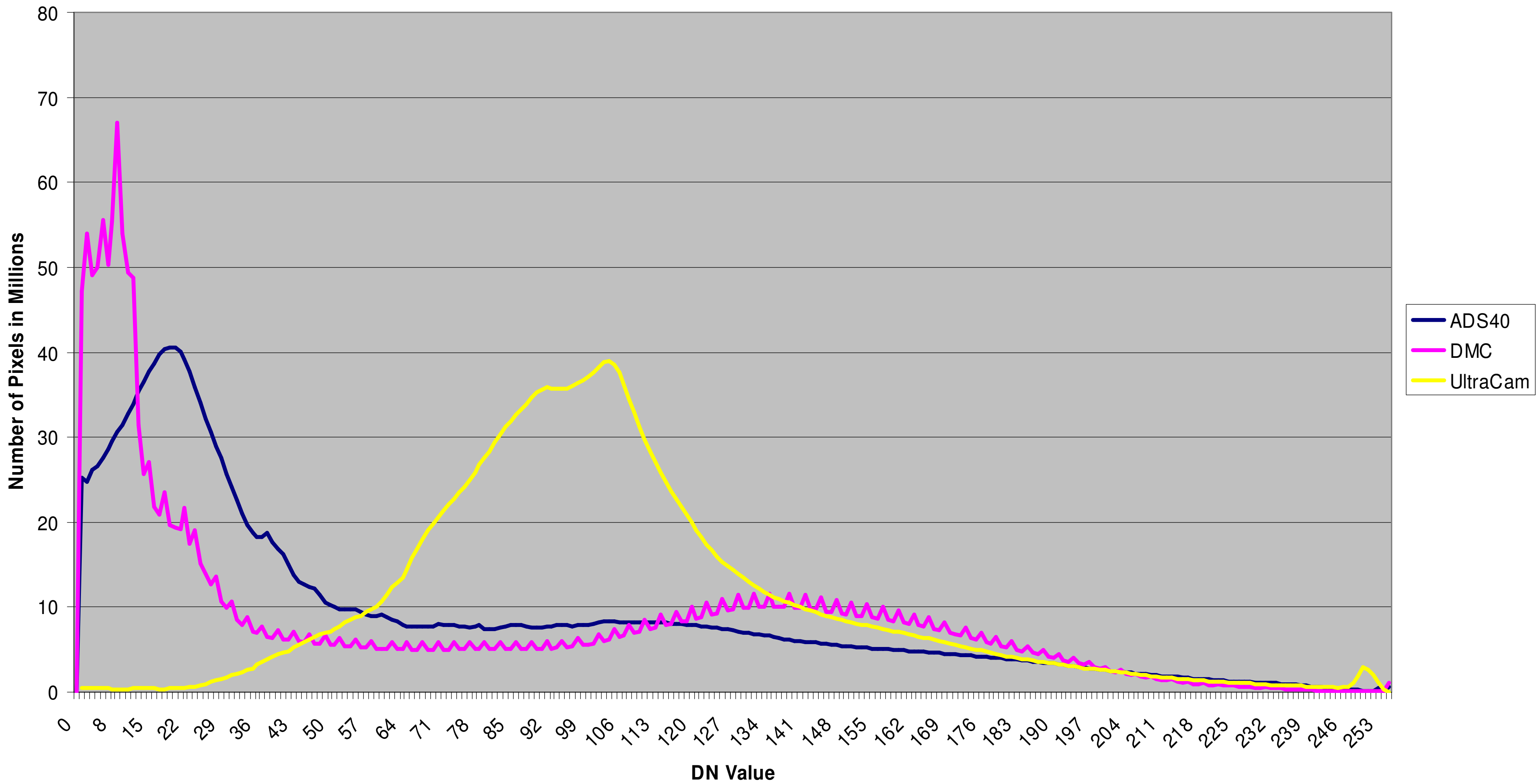
Band 2 (Green) Comparison



Band 3 (Red) Comparison



Band 4 (Near Infrared) Comparison



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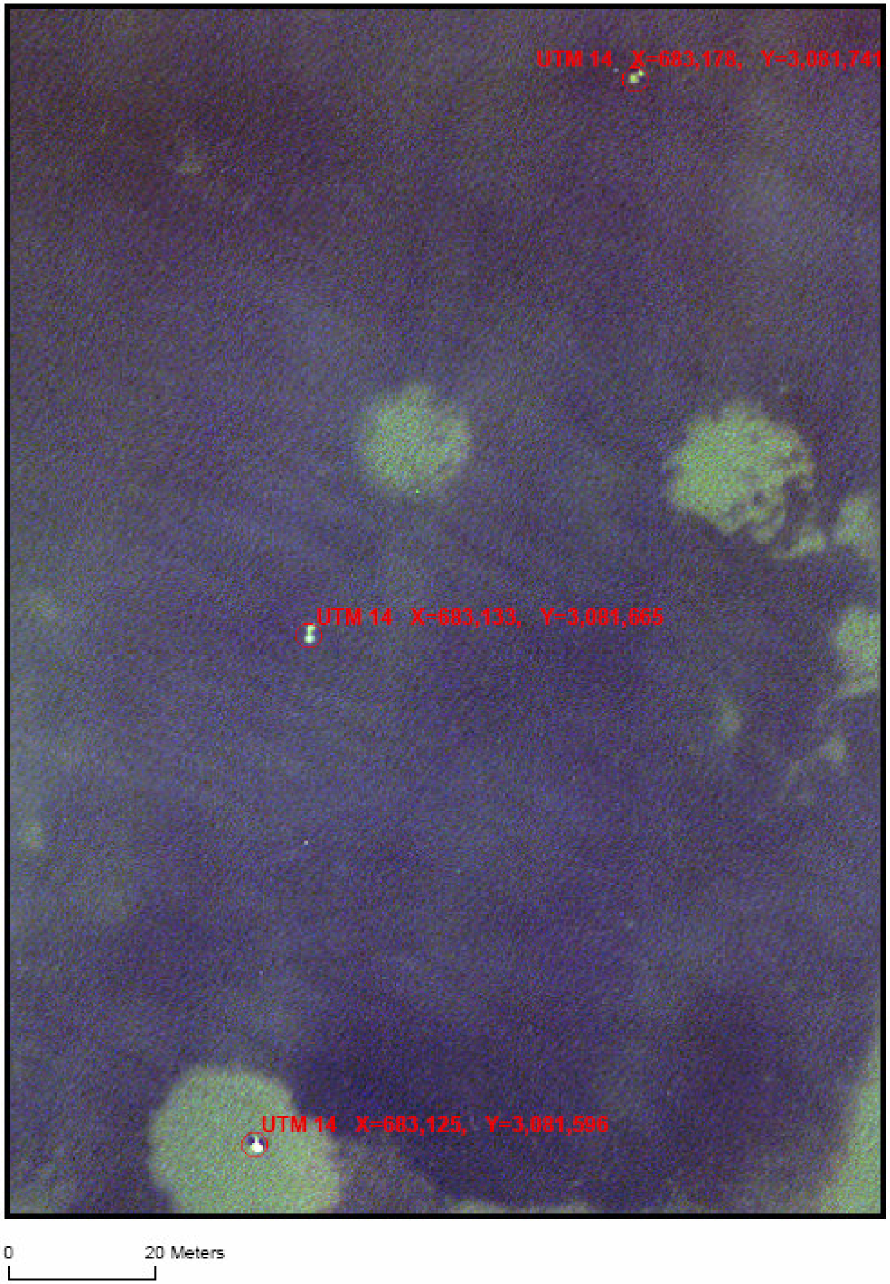
C. Edge Detection

- To evaluate how each sensors registered edges, three targets were submerged in the study area at 1, 1.5, and 2 meters prior to the image capture.
- Submerged targets at 1, 1.5, and 2 meter depths were visible and the target patterns were distinguishable in all three image sets.

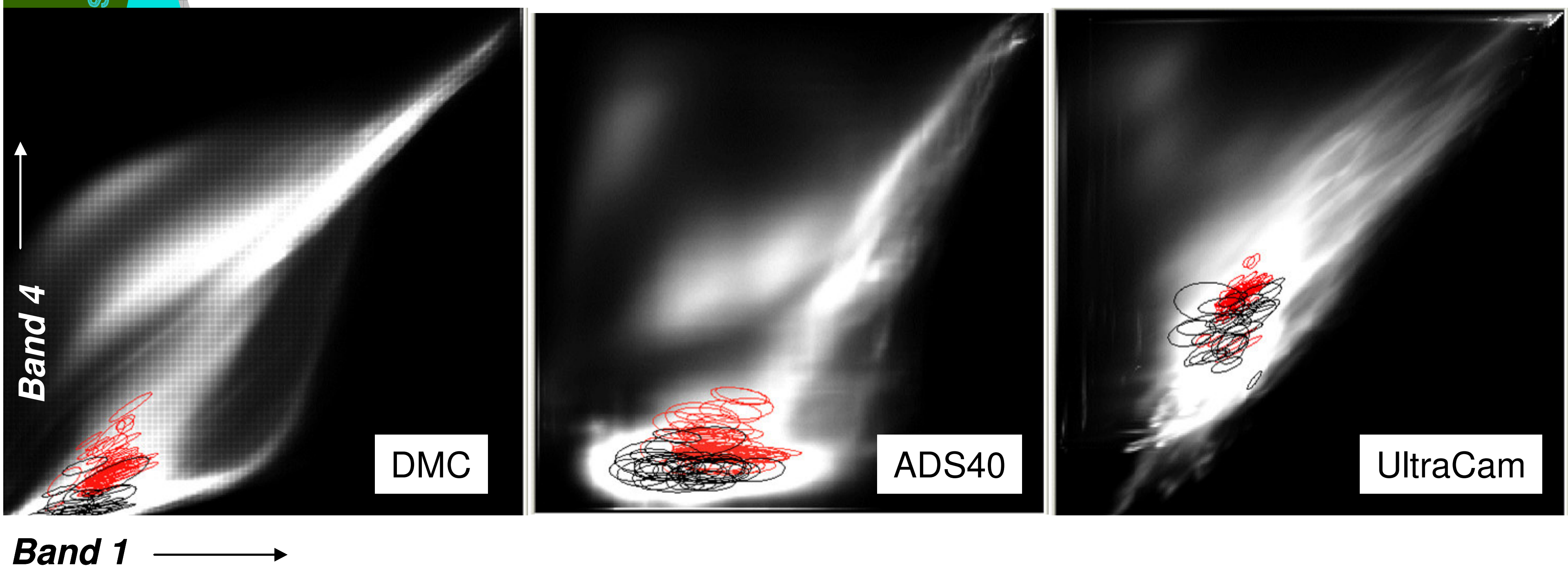
ADS40 Imagery with Overlaid Locations of John Wood's Targets



D. Spectral Separability

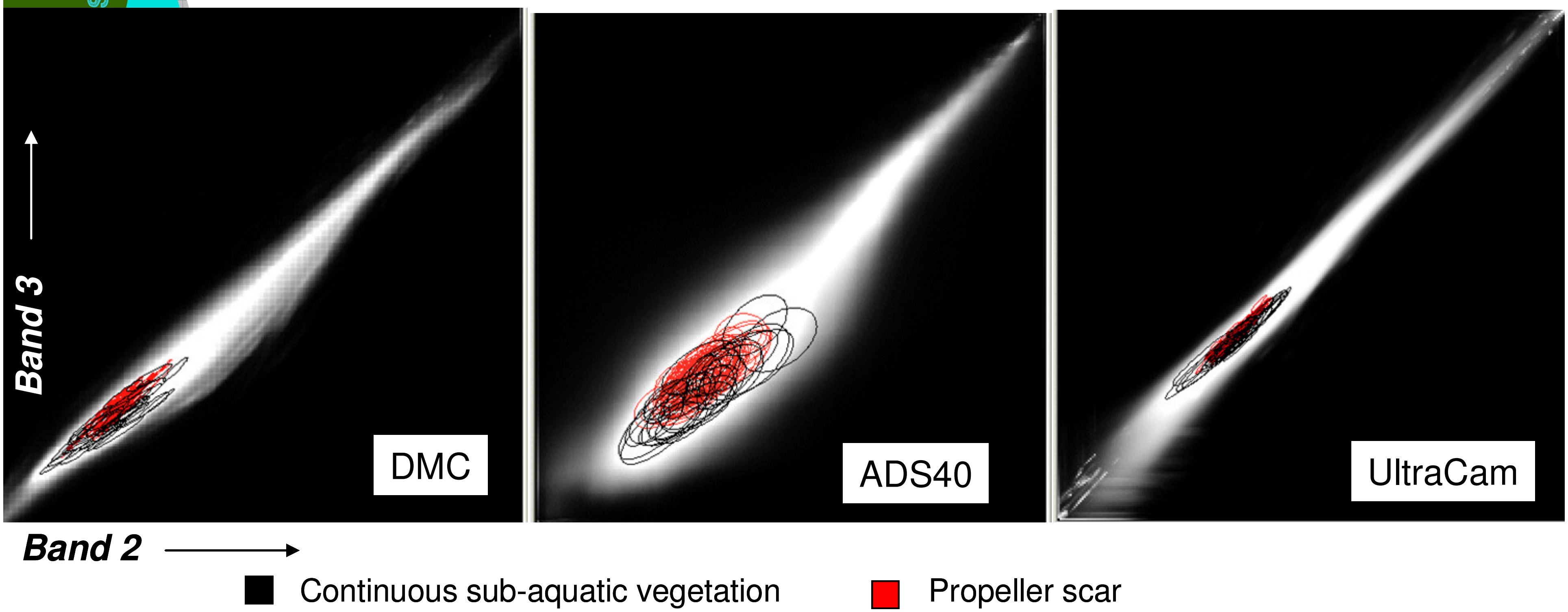
- To test the spectral separability of habitat classes from one another in each image data set, training sites of each benthic habitat class were collected.
- Bi-spectral plots were created for all band combinations.

Band 1 vs. Band 4

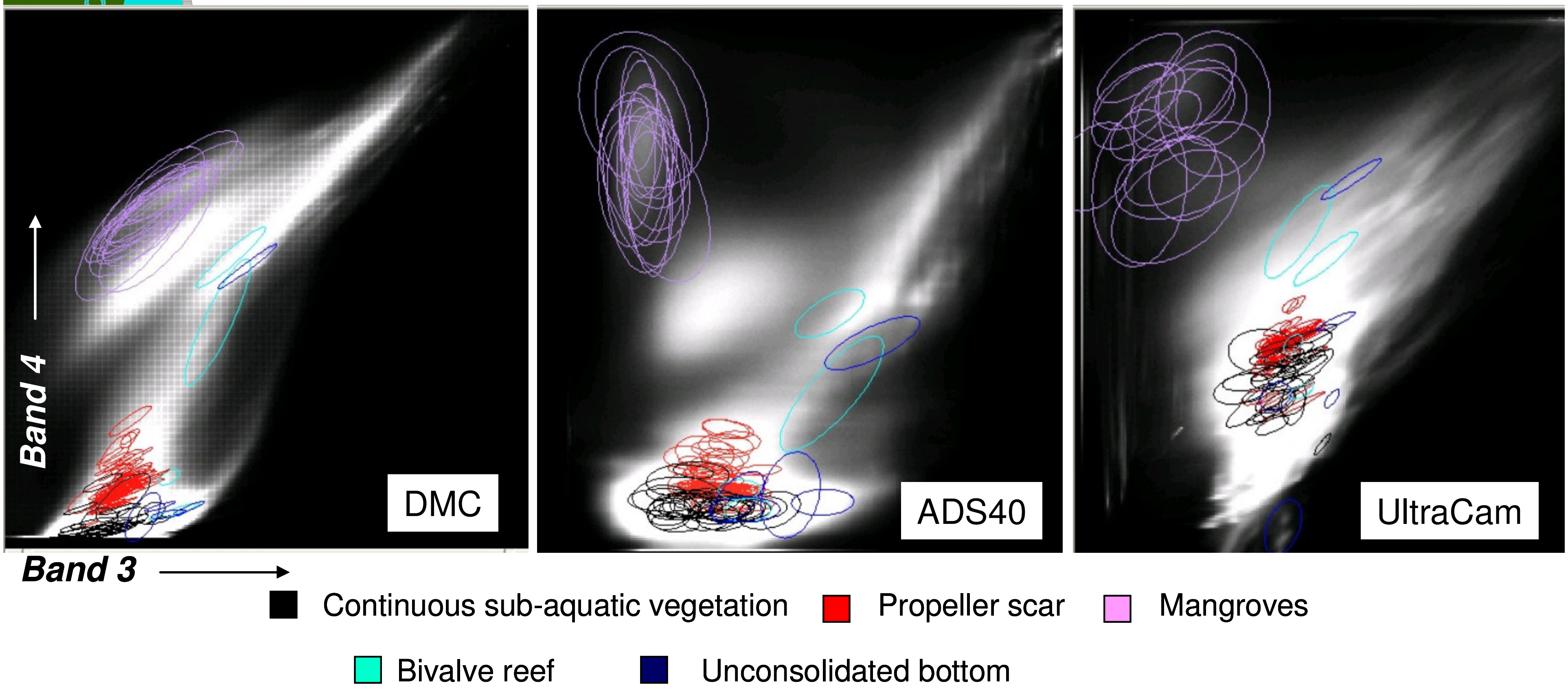


■ Continuous sub-aquatic vegetation ■ Propeller scar

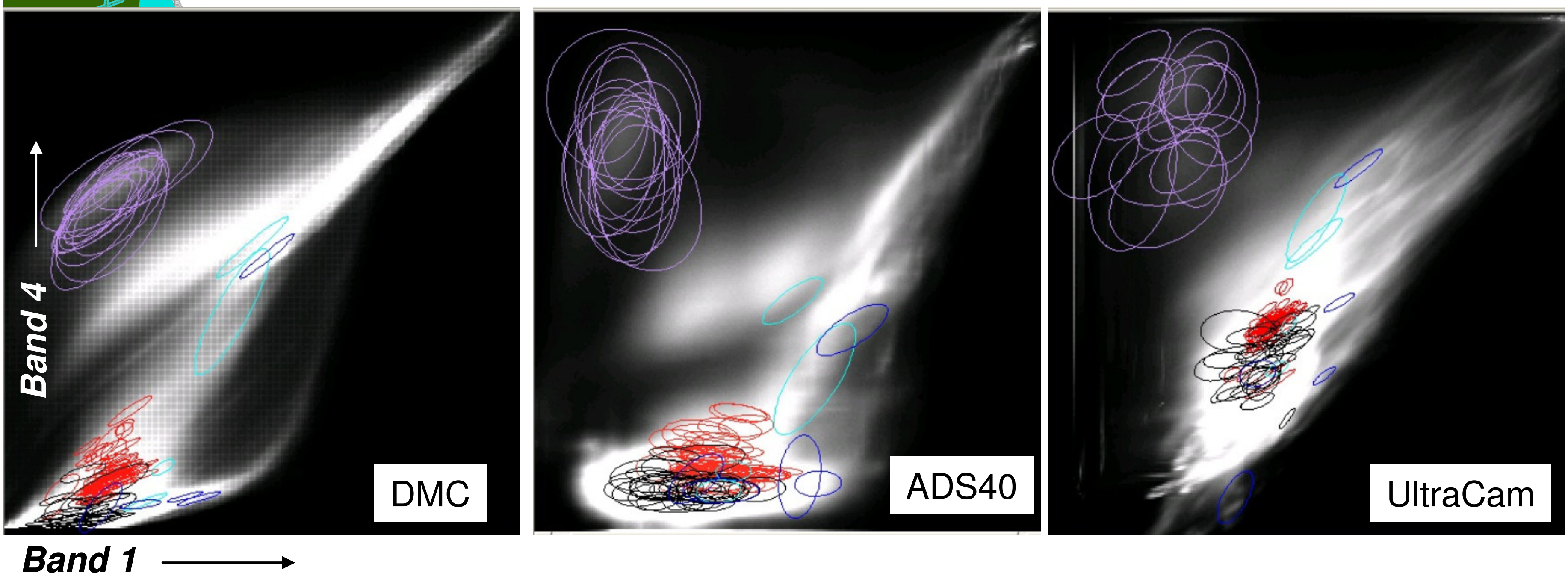
Band 2 vs. Band 3



Band 4 vs. 3


Band 4
Band 3
DMC
ADS40
UltraCam
Continuous sub-aquatic vegetation
Propeller scar
Mangroves
Bivalve reef
Unconsolidated bottom

Band 1 vs. Band 4



■ Continuous sub-aquatic vegetation ■ Propeller scar ■ Mangroves

■ Bivalve reef ■ Unconsolidated bottom

Bi-Spectral Results

- Prop scars are clearly distinguishable in the ADS40-52 and DMC data, but somewhat confused in the UltraCam data.
- Very little spectral distance exists between prop scars and sub-aquatic vegetation in the visual bands.
- Mangroves are spectrally unique in all image sets.
- Bivalve reefs and unconsolidated sediments will probably require additional data (such as shape or texture) to be reliably mapped from any of the image sets.

Qualitative Review

- All of the image sets were comparatively reviewed by seven remote sensing professions, three of whom were also benthic habitat mapping experts.
- The purpose of the qualitative evaluation was to determine the suitability of the imagery derived from the three digital sensors for mapping submerged prop scars and benthic habitat.
- Benthic habitat classes to be considered were Continuous and Patchy Submerged Rooted Vegetation, Unconsolidated Sediments, Bivalve Reef, Unknown Benthic Habitat, Mangroves, Emergent Marsh, Other Land

Overall, All Image Sets Garnered Praise

- "The imagery for all of the data sets was tone corrected for good contrast in the shallow water areas."
- "Overall, the prop scars are clearly visible in all 3 sets of imagery…"
- "All of these instruments are very clean and produce excellent qualitative images."
- "The three systems appear comparable in the ability to clearly render SAV and other types of shallow water features."
- "The imagery from all three systems clearly shows propeller scarring, even very fine and detailed networks of scarring are clearly visible in the imagery from all three systems."

5. Propeller Scar Maps

- Used Feature Analyst
- All image sets received absolutely the same FA workflow
- Feature Analyst Parameters
  - ✓ *Input Bands:* All (NIR And R,G,B)
  - ✓ *Find rotated instances of features:* Turn on
  - ✓ *Learning algorithm:* General purpose
  - ✓ *Aggregate Areas:* 4 pixels (later aggregated up to MMU using eliminates)
  - ✓ *Resample Factor:* 1 (image data is not resampled)
  - ✓ *Apply Histogram Stretch:* No
- No Editing

Overall Accuracies

- The prop scar maps produced with the ADS40-52 data are substantially better (85% overall accuracy) than the maps produced from the DMC or UltraCam data (76% and 60% overall accuracy, respectively).
- We believe that the higher spatial resolution and higher spectral fidelity of the ADS40-52 multispectral data may be the cause of the difference.

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ADS52 Accuracy Assessment -

			Reference		
		no prop scar	prop scar	Total	Comsumer's Accuracy
	no prop scar	52	31	83	63%
	prop scar	0	124	124	100%
Map	1-20% prop scar	0	16		
	21-40% prop scar	0	20		
	41-60% prop scar	0	22		
	61-100% prop scar	0	66		
	Total	52	155	207	
	Producer's Accuracy	100%	80%	Overall Accuracy	85%

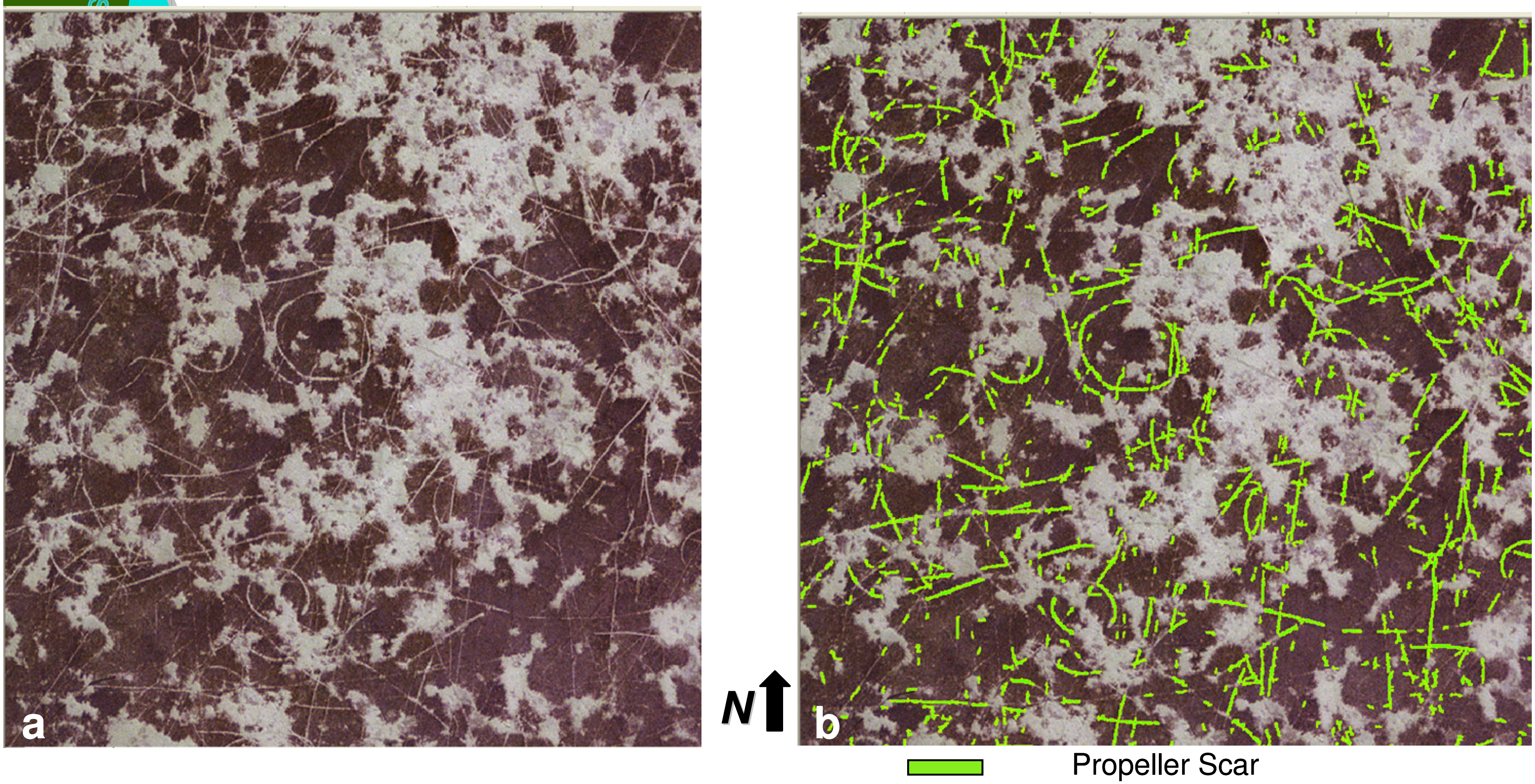
DMC Accuracy Assessment

			Reference		
		no prop scar	prop scar	Total	Comsumer's Accuracy
	no prop scar	52	49	101	51%
	prop scar	0	106	106	100%
Map	1-20% prop scar	0	21		
	21-40% prop scar	0	18		
	41-60% prop scar	0	17		
	61-100% prop scar	0	50		
	Total	52	155	207	
	Producer's Accuracy	100%	68%	Overall Accuracy	76%

UltraCam Accuracy Assessment

			Reference		
		no prop scar	prop scar	Total	Comsumer's Accuracy
	no prop scar	52	82	134	39%
	prop scar	0	73	73	100%
Map	1-20% prop scar	0	16		
	21-40% prop scar	0	17		
	41-60% prop scar	0	15		
	61-100% prop scar	0	25		
	Total	52	155	207	
	Producer's Accuracy	100%	47%	Overall Accuracy	60%

Propeller Scar Map



Conclusions

- Digital airborne UltraCam, ADS40-52, and DMC imagery can be used successfully to map benthic habitat types and propeller scars.
- The three image data sets were collected under almost identical weather and tidal conditions, indicating that differences between image sets and maps created from them are most likely due to differences in the sensors and in any processing applied to the imagery.
- In shallow water, the infrared band is an important discriminator among benthic classes and between benthic habitat classes and propeller scars.

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Conclusions

- Propeller scars comprise less than 1% of the area of Redfish Bay, but are ubiquitous throughout the shallow areas of the Bay, significantly fragmenting seagrass beds.
- Automated image classification of ADS40-52 imagery, relying on Feature Analyst augmented with CART modeling, can be used to successfully identify and map the majority of propeller scars in seagrass beds. Mapping of every single scar requires supplemental manual digitizing.
- All reviewers found all three image data sets to be suitable for benthic habitat and propeller scar mapping. However, significant inconsistency between the reviewer's opinions made it impossible to use the qualitative reviews to rank the quality of the systems against one another.

Conclusions

- Quantitative analysis points to some significant differences between the image data sets.
  - ✓ The spatial accuracy of all three sensors greatly exceeded contract standards with the DMC and ADS40-52 having statistically better spatial accuracy than the UltraCamD at the 95% confidence level.
  - ✓ Spectral separatability of benthic habitat classes and propeller scars is best in the DMC and the ADS40-52 imagery.
  - ✓ Propeller scar maps produced from the automated classification of the ADS40-52 imagery were significantly more accurate than those produced from the DMC or UltraCam imagery; and propeller maps produced from automated classification of the DMC imagery are significantly more accurate than those produced from the UltraCam imagery.

Finally

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- The State of Texas Parks and Wildlife Department continue to use these methods to monitor propeller scar damage in Redfish Bay.
- This is one of the best projects I have ever worked on. Thanks to Dennis Hall for the “recreational employment”!